Nematodes:

Nice, not naughty

John Sanderson
Anna Giesmann

Entomology
Cornell University

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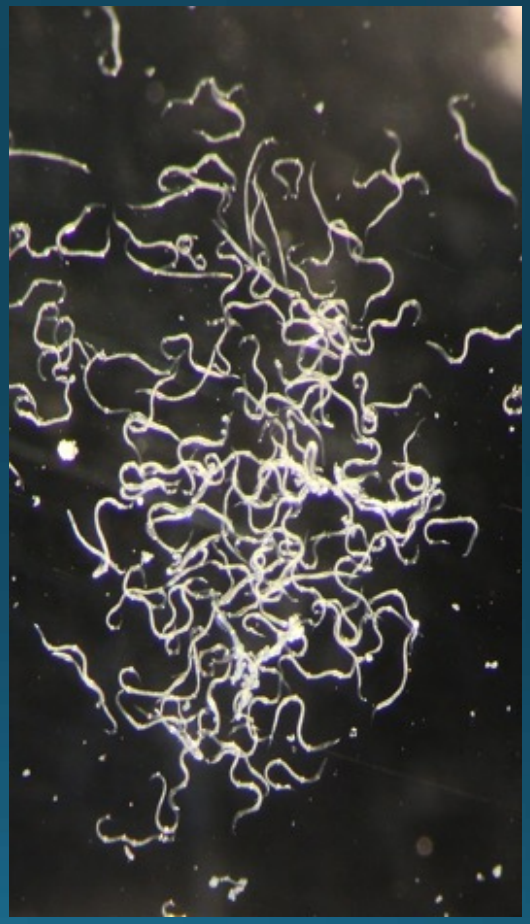
Things to Cover:

- Background
  - Who uses nematodes?
  - What are they?
  - Key pests
- Nematode Applications
  - Available Products
  - Steps & tips
  - Technology
- Ensuring efficacy
  - Potential pitfalls
  - Research in our lab
  - Integrating nematode with other control options



Nematodes in the Greenhouse Industry

Greenhouse Grower Magazine's
2017 State of the Industry:

- 975 respondents
- 63% of growers use biological control
- One of biggest crop protection issues = **Thrips control**
  → *nematodes* as best solution

Nematode use increased because of:

- Increased awareness & understanding
- Better quality and application technology
- Decreasing prices
- Necessity

2017 survey results from NYS greenhouse businesses:

Grower Plans for Fungus Gnats

% Responding	Pest Mgt. Tactic	
40	Insecticides	
35	Biological Control	
8	Biocontrol & Insecticides, on separate crops	
17	Biocontrol & Insecticides, on same crops	
For Biocontrol:	**% Using**	**Biocontrol Agent**
	25	Hypoaspis/Stratiolaelaps predatory mites
	42	Nematodes
	28	Gnatrol (Bt var. israelensis bacterium)
	6	Atheta/Dalotia rove beetles

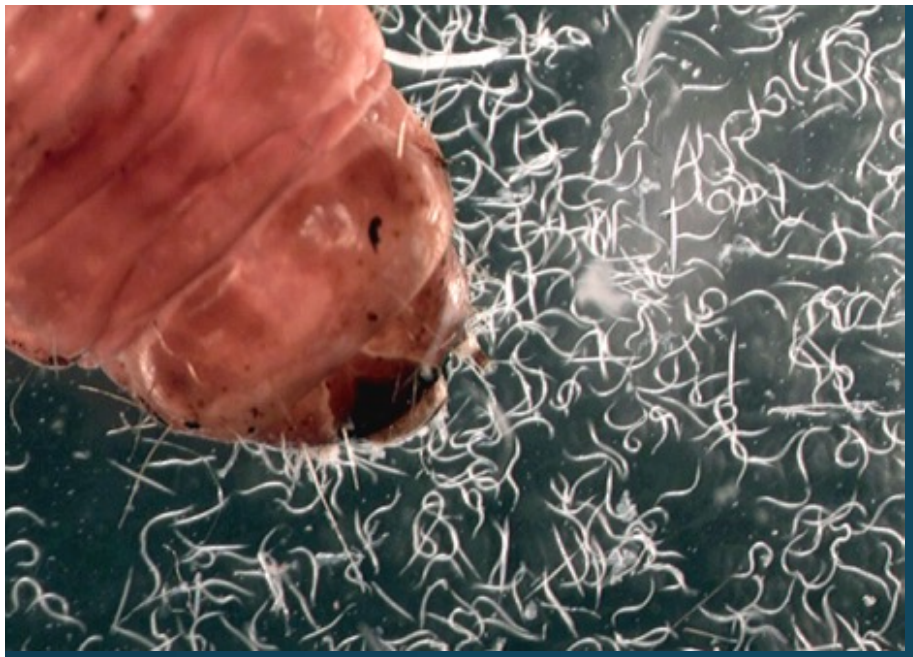
2017 survey results from NYS greenhouse businesses:

Grower Plans for Thrips

% Responding	Pest Mgt. Tactic	
45	Insecticides	
21	Biological Control	
11	Biocontrol & Insecticides, on separate crops	
21	Biocontrol & Insecticides, on same crops	
For Biocontrol:	**% Using**	**Biocontrol Agent**
	21	Hypoaspis/Stratiolaelaps predatory mites
	23	Nematodes
	20	Cucumeris/swirskii predatory mites
	9	Orius bugs
	27	BotaniGard/Naturalis/Preferal fungi

Nematodes Basics

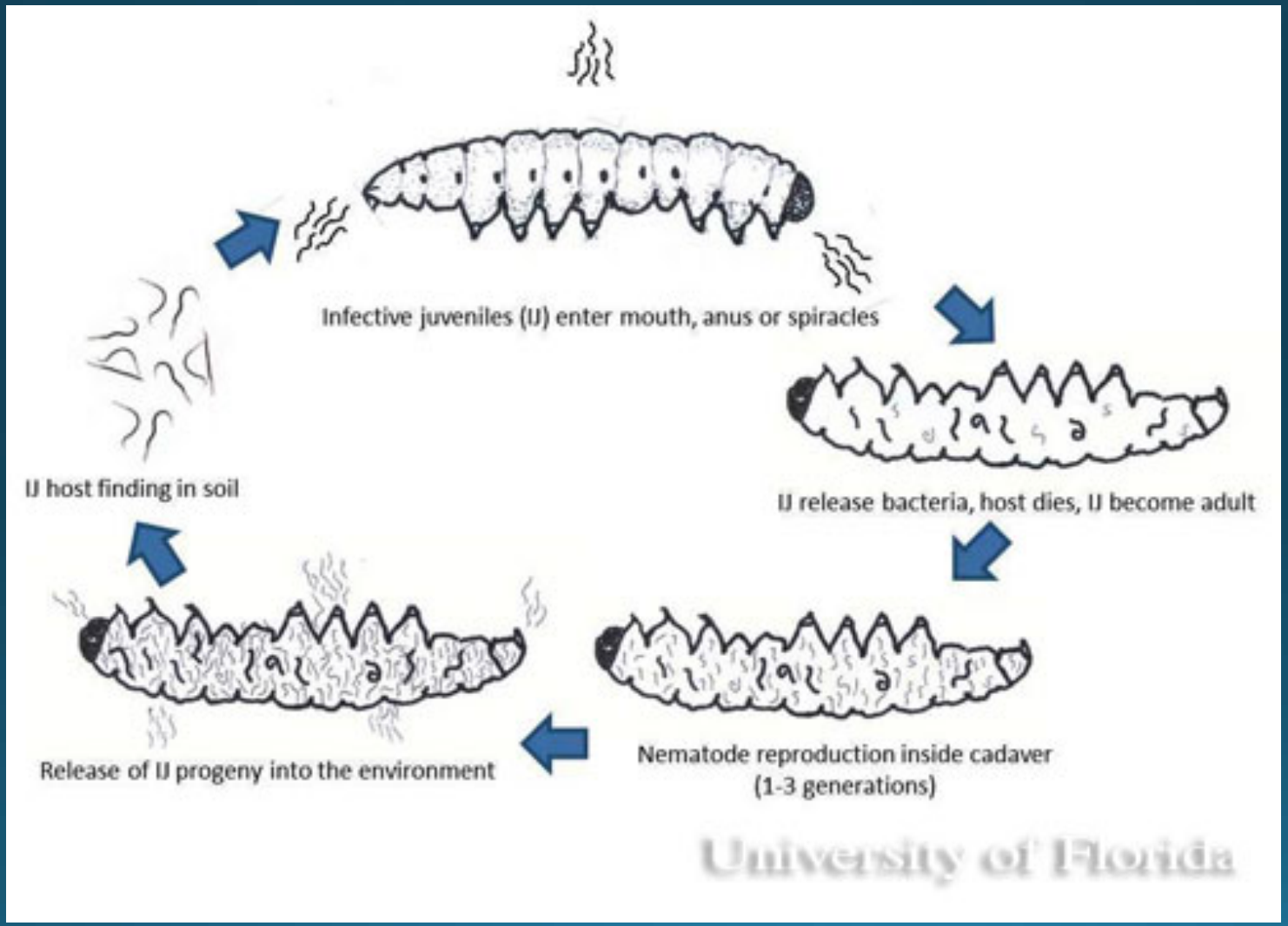
- Most abundant land animal on earth (?)
- Roundworms
  - Phylum Nematoda
  - Harmful *and* helpful species
- For biological control
  - Insect-killing, or "entomopathogenic" nematodes (EPNs)
  - Virtually no risk of resistance
  - No REI or PHI
  - Apply preventatively



Entomopathogenic Nematodes (EPNs)

- Microscopic
- Soil-dwelling
- Need water film to disperse
- Develop inside insect hosts
- Carry *bacteria* responsible for insect death

Generalized Life Cycle of Insect-killing Nematodes:

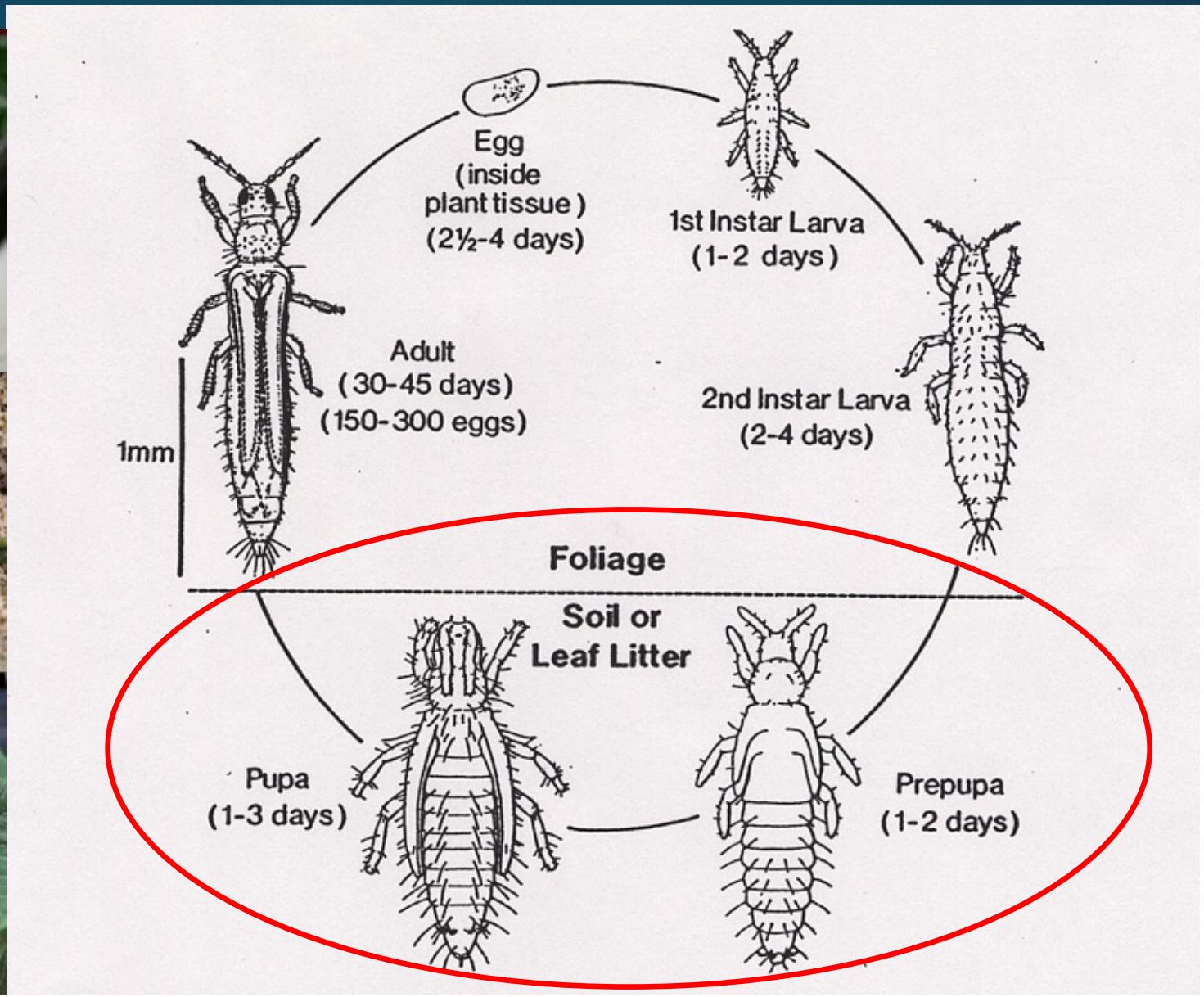


Fungus Gnats

Healthy larva

Infected larva

Western Flower Thrips



Thrips and nematodes

Yes - Western flower thrips

?? - Onion thrips

No - Echinothrips ("Poinsettia thrips")

No - Greenhouse thrips

WFT Pupae

Before Infection

After Infection

Shore Flies

No direct damage, but…

- black specks
- soil-borne pathogens
- nuisance

Reducing algae is best control, but nematodes can help!

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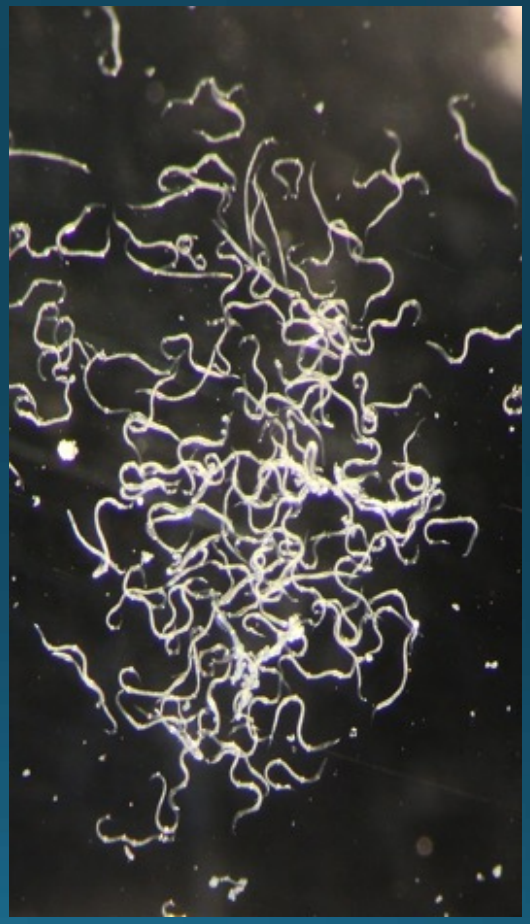


Widely Available Nematodes

Steinernema feltiae
Steinernema carpocapsae
Heterorhabditis bacteriophora

Variations in:

- Host insects attacked
- Environmental tolerance
- Price

EPN-infected thrips pupa

Steinernema feltiae is most commonly used nematode

Steinernema feltiae

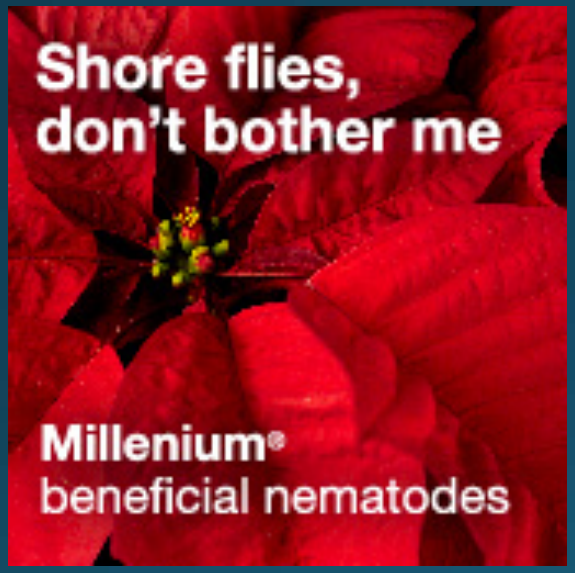
Characteristics:

- Controls FG, WFT, (shore fly, black vine weevil, white grubs, etc.)
- Cool-Mid temperature range
- Often lowest-priced nematode products

Available Products:

NemaShield
Nemasys
Scanmask
Entonem
Steinernema-System
Exhibitline SF
E-Nema
and more…

Steinernema carpocapsae



Characteristics:

- Marketed to control shore flies, weevils, grubs, mole crickets, etc.
  - Can also help control FG and WFT
- Mid-High temperature range
- Less commonly used → sometimes higher price

Available Products:

Millenium
Nematac C
Ecomask
Capsanem
Exhibitline Sc
Carpocapsae-System
and more…

Heterorhabditis bacteriophora


Bioline

Characteristics:

- Marketed to control weevils, white grubs (European chafers, Oriental and Japanese beetles)
  - Can help with FG, WFT, and shore flies (??)
- Mid temperature range
- Less commonly used → sometimes higher price

Available Products:

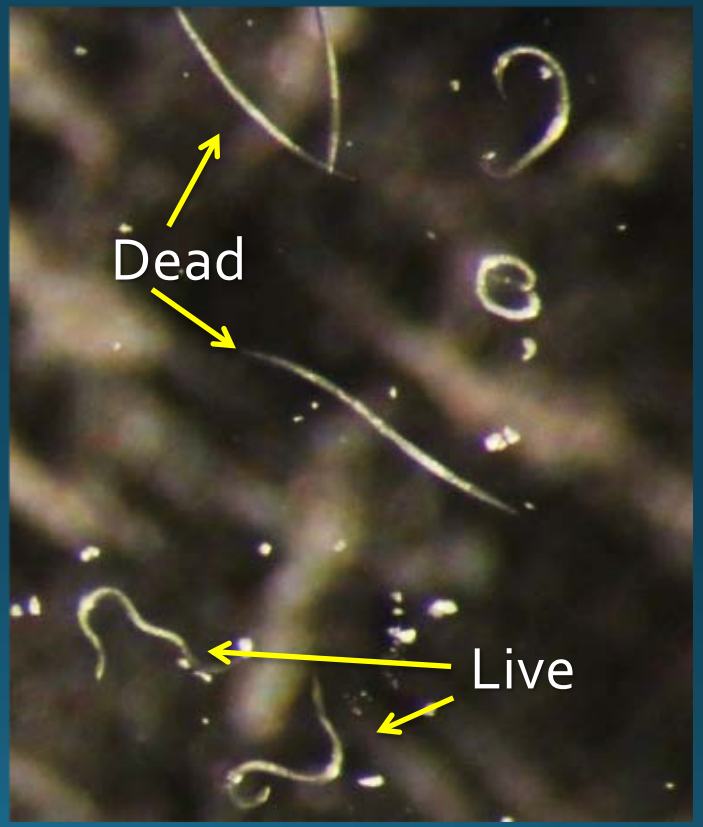
Nemashield HB
Nemasys G
Heteromask
Larvanem
B-Green
and more…

Nematode Products

- Most common: trays with 50, 150, or 250 million nematodes
- Sponges, granule, and vermiculite mixes exist, but much less common than gels
- Best to use as soon as possible
- May be stored in refrigerator (40°F)
- Check expiration date
- If package is opened, do not store*

Checking Nematode Viability

- Let the package come to room temperature for 30 min
- Place a very small sample on a dark plate or dish
- Add 1 drop of water
- Wait about 5 minutes, then observe with lens or microscope
- Can also take sample from spray solution to check for live nematodes



Application Technology

- Almost any full-volume sprayer can be used
  - Keep pressure below 300 psi
  - Remove filters and screens!
  - Nozzle should have adequate openings
  - Agitation – nematodes drop out of suspension

- Some irrigation systems
  - Better distribution with boom sprayers than drip, sprinkler systems

Avoid mixing with incompatible pesticides

Aeration/Agitation Bucket-Battery Operated

Ferticart 50 Gallon with Aeration/Agitation

Dramm Agitation/Aeration Bucket

Basic Steps for Nematode Application

- Pre-wet soil, if possible
- Remove from fridge, ~30 min to warm up
- Mix into water
  - <u>Less than 100F!!</u>
  - Cold tapwater OK
- Apply, <u>agitating regularly</u>

Nematode Application

Double row of nozzles on boom sprayer:

1st row – nematodes
2nd row – water to flush into soil

Biocontrol with Nematodes in the Real-World

Great YouTube video at UMass Floriculture:

Using Beneficial Nematodes to Manage Pests in Greenhouses

https://www.youtube.com/watch?v=Y67yhIIQdLU

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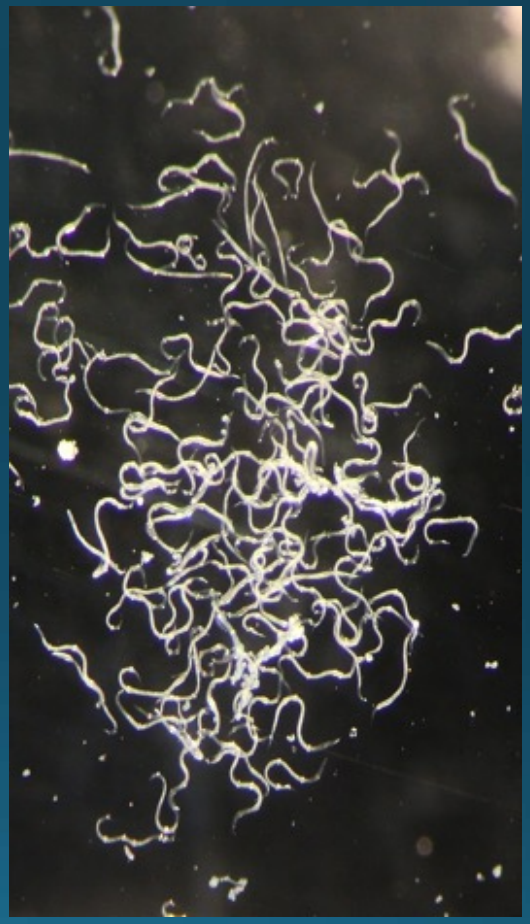


Ensuring Nematode Efficacy

Risks	Safeguards
Dry growing mix Desiccation Impaired mobility	Make sure media is moist before nematode application.
UV light	Apply early morning or evening
High pressure	Keep spray pressure in equipment below 300 psi
High temperatures	Avoid hot afternoons Avoid hot water for mixing Use heat-tolerant species in summer

Ensuring Nematode Efficacy

Risks	Safeguards
High chlorine in water	Tap water is generally safe
Incompatible pesticides in tank in growing mix	Check side effects lists for EPNs Stay aware of possible effects of whatever you add to the mix

Pesticide compatibility

with insect-killing nematodes

BioBest, Koppert have Side Effects Lists

Compatibility info also available on most biocontrol company websites

BASF Compatibility Chart:

Addresses adjuvants, insecticides, fungicides

Puts active ingredients into following categories:

- Suitable for Tank Mixing
- Apply Separately
- Separately, 7 day Intervals
- Separately, 14 day Intervals

https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-chemical-compatibility-guide.pdf

Experiment 1:

Nematode Persistence in Growing Media

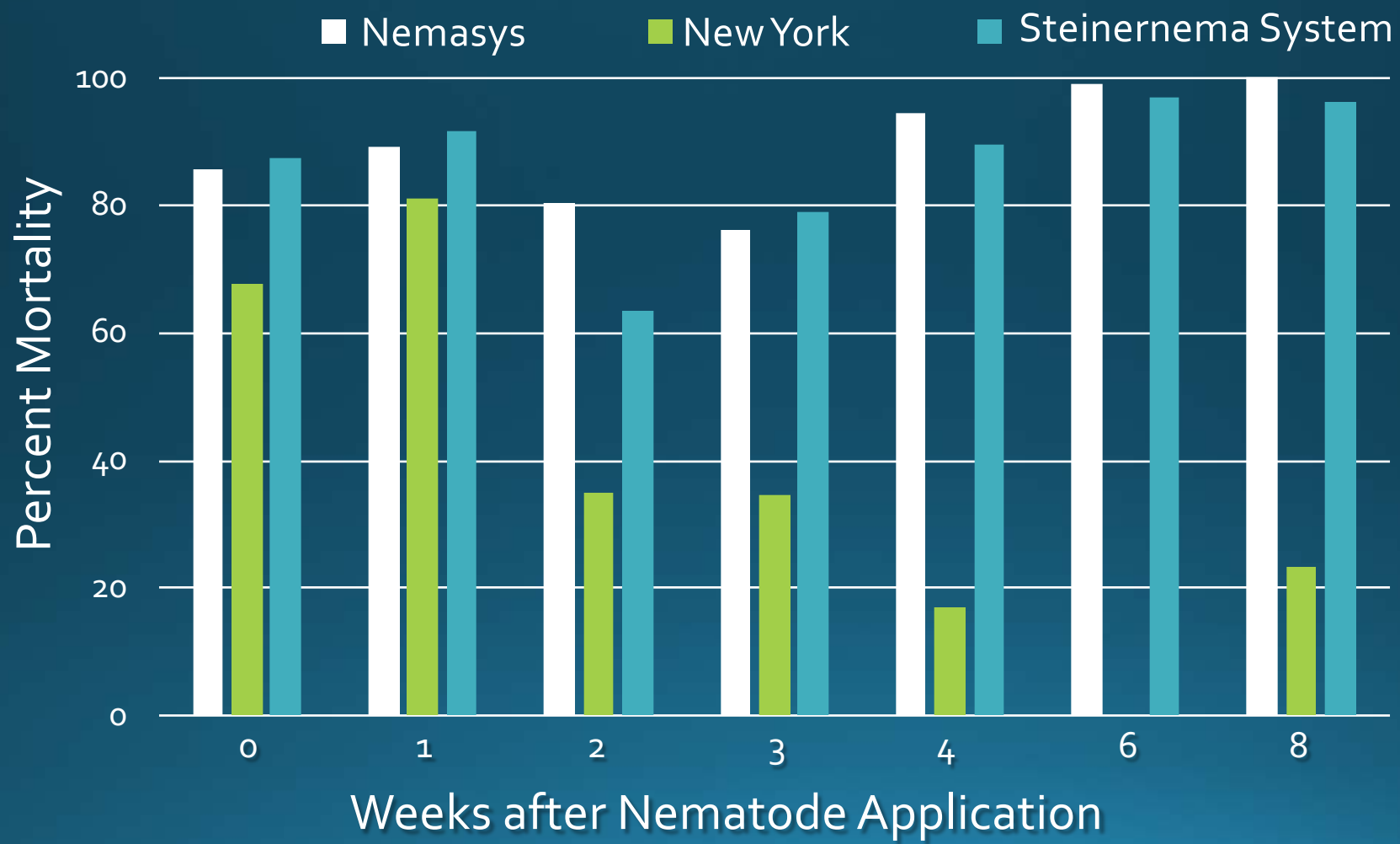
How long can nematodes remain active and infective after a single application?

-Commercial recommendation is usually every 2 weeks, but some claim 6 is adequate…

Nematode Persistence in Growing Media

- 3 *S. feltiae* products: Nemasys™, native New York strain, Steinernema-System™
- Single initial drench @ 36,000 IJs per pot
- Then add 30 late-instar FG larvae after 0, 1, 2, 3, 4, 6, or 8 weeks
- 5 pots per treatment per week
- Pots were sub-irrigated in trays
- 2 weeks after introducing FG, count new adults on traps

Percent mortality of fungus gnats after single initial nematode application



Nematode Persistence in Media

Eight weeks control after single drench???

However, the pots were sub-irrigated…

Overhead watering may wash some nematodes out of the pots.

Experiment 2:

Overhead Watering vs. Subirrigation

Mortality is consistently >80% for 2 weeks after initial application; differs afterwards.

→ Should apply once every 2 weeks for fungus gnats.

Effect of growing substrate

Dwight Sipler via Wikimedia Commons

Peat-based growing mix

Nematodes may wash out of rockwool

Rockwool

Experiment 3:

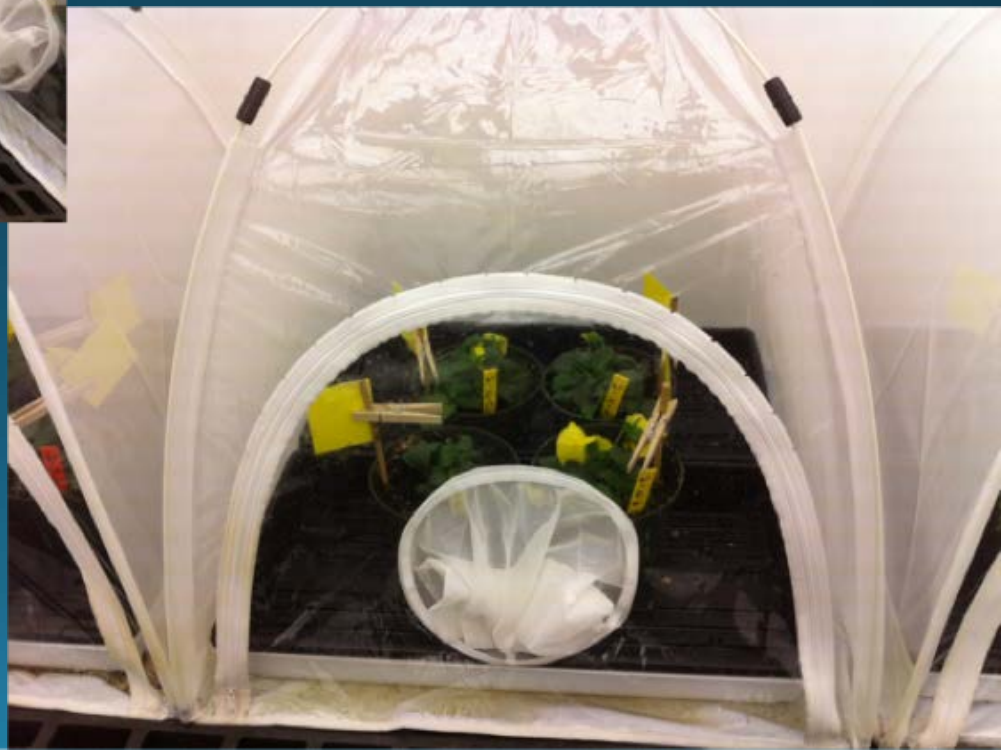
Effects of cool temperatures on nematode control of fungus gnats

Will FG still be a problem at cooler temperatures, and will nematodes be able to infect them?

Experiments carried out in bugdorms within growth chambers

"Warm" chamber = 75F
"Cool" chamber = 55F

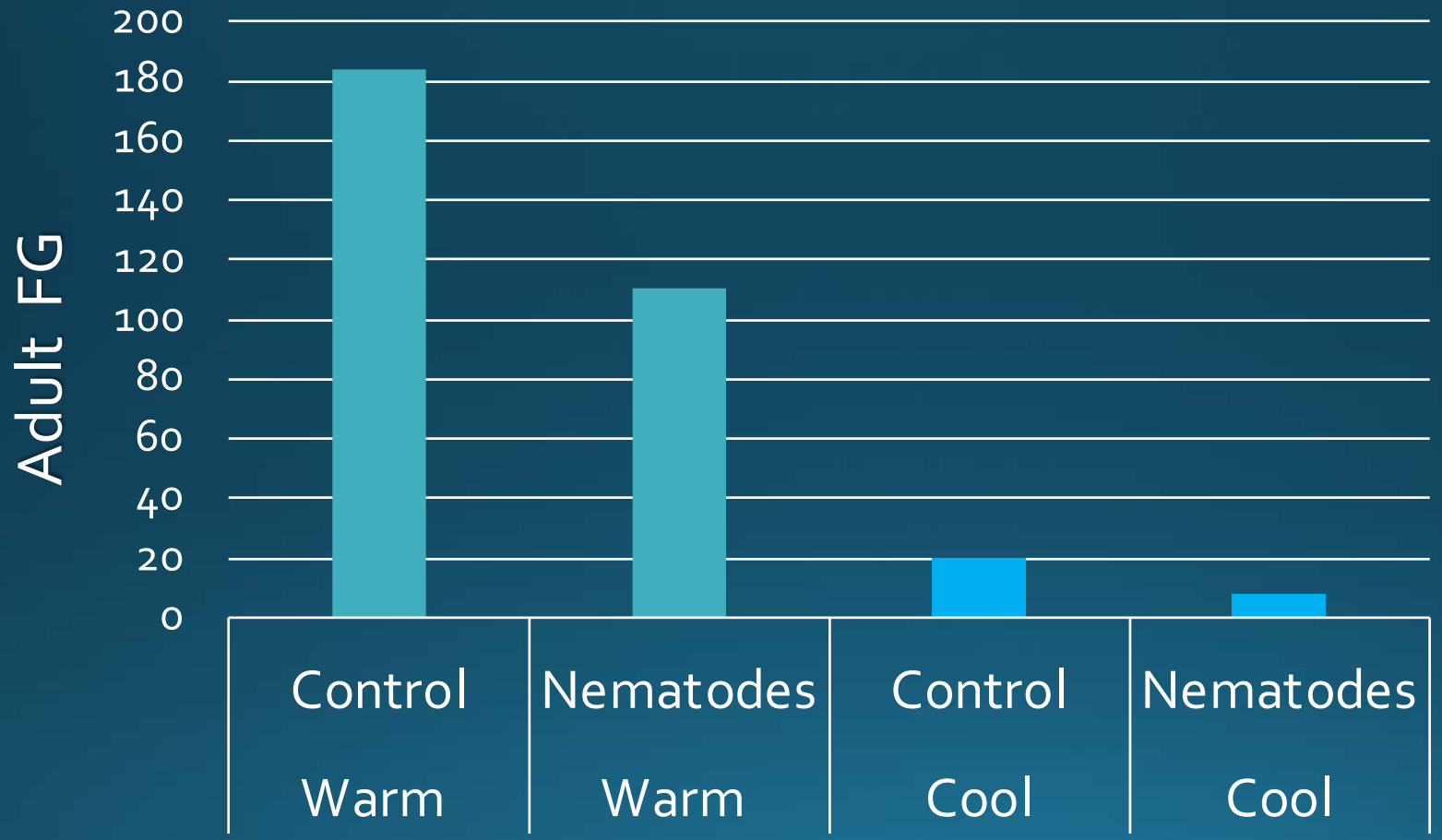
Equally infested with FG adults



Treatments:
- 2 Nemasys drenches, 2 weeks apart
- Untreated control
- 5 cages of each

Traps added after 15 days

Average adult FG trapped in cages after two nematode drenches, in warm or cool environments



Conclusion from Exp. 3:

With Nemasys nematodes against high FG infestation:

Warm temps = 40% control
Cool temps = 60% control

→ *S. feltiae* nematodes work well at low temps!

Ensuring Nematode Efficacy

High temperatures	**Avoid hot afternoons** **Avoid hot water for mixing** **Use heat-tolerant species in summer**

But how hot is "hot"??

"Experiment 4"
(series of experiments)

M.S. thesis research by Anna Giesmann

"Experiment 4":

High temperature tolerance for Heterorhabditis bacteriophora (Hb), Steinernema carpocapsae (Sc), and Steinernema feltiae (Sf)

- Exposed all 3 species (and 3 strains of each species) to 86, 95, 104, or 113F, and each temperature for 1, 2, 4, 6, 8, or 10 hours.
- Evaluated survival (infectivity tests underway)

- Preliminary results, but fair amount of confidence.

Experiment 4:

Tentative Takehome Messages

Research still underway!

Tolerance to high temps

S. feltiae (NemaShield, Nemasys, Steinernema-System, Entonem, ExhibitLine sf) is most susceptible to high temperatures (lots of mortality ca. 95F)

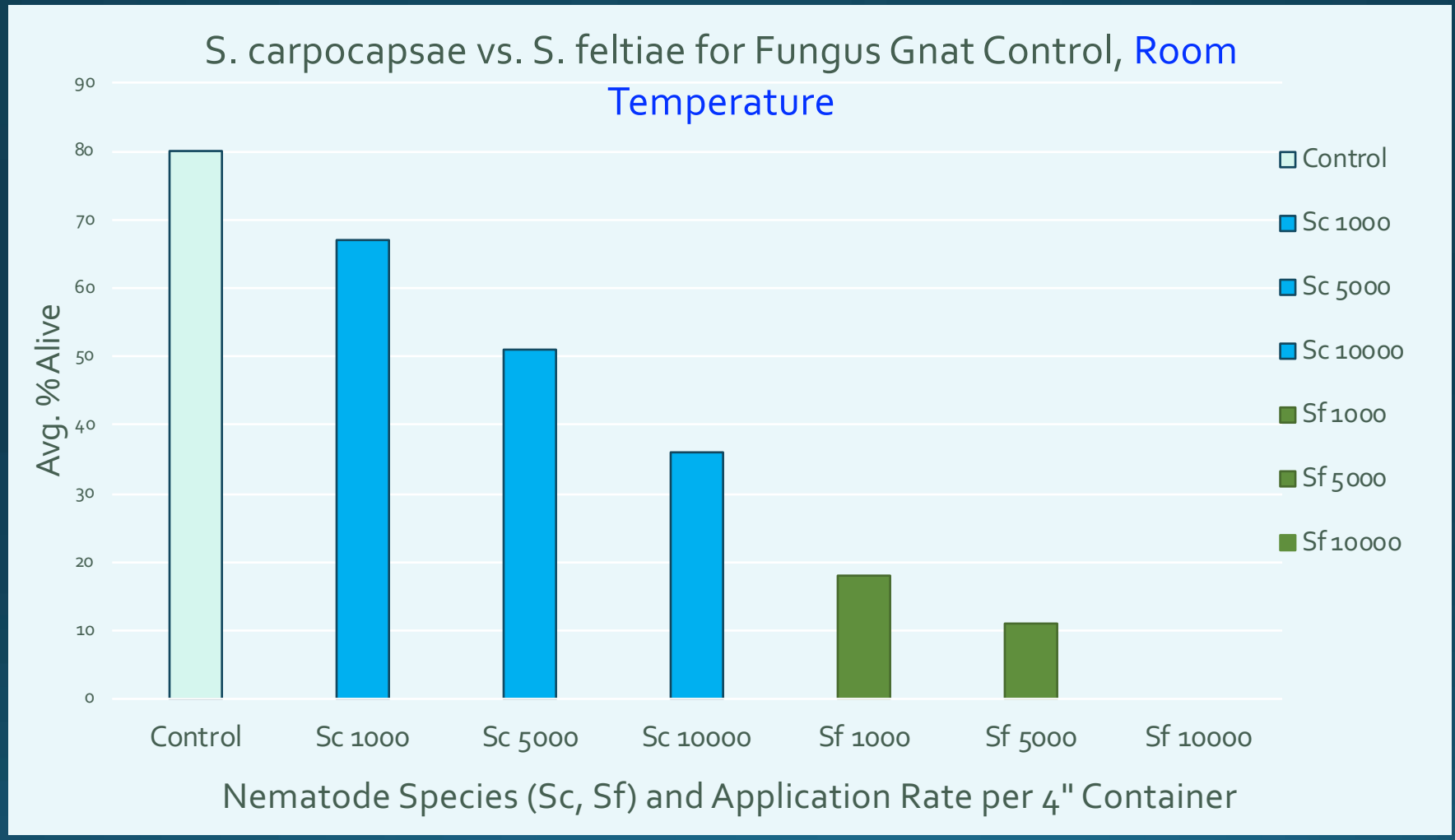
least

H. bacteriophora (Larvanem, Terranem, B-Green, Exhibitline hb, Nemasys G) had 100% mortality after 4 h at 104F

S. carpocapsae (Millenium, Exhibitline sc, Sportnem T, Carpocapsae-System) is least susceptible to high temperatures (only species that survived at all at 113F)

most

→ More research yet to do, but maybe use heat-tolerant species whenever water or substrate temps exceed 95F?



Results may look very different at high temperatures

Integrating nematodes with other beneficial arthropods

Predaceous Mites + Nematodes for Thrips

- Nematodes kill pupal stages in soil
- *A. cucumeris* or *A. swirskii* mites kill first-instar thrips on foliage
  - Applied in broadcast mixtures or sachets
- Compatible biocontrol!

Other Compatible Biocontrol Combinations

For foliar control of thrips, can also use:

- Predatory bugs such as *Orius*

Or

- Entomopathogenic fungi

BotaniGard may not be compatible with Orius!

Biocontrol combinations for fungus gnats

Nematodes plus:

- ✓ Strateolaelaps/Hypoaspis mites
- ✓ Gnatrol
- ✓ Rove beetles
  (S. feltiae is OK)
- ? Hunter Flies

Resources

- Article from U Mass Greenhouse Crops and Floriculture Program. Website also includes demonstration video!

https://ag.umass.edu/greenhouse-floriculture/fact-sheets/biological-control-using-beneficial-nematodes

- BASF guide for use of Nemasys

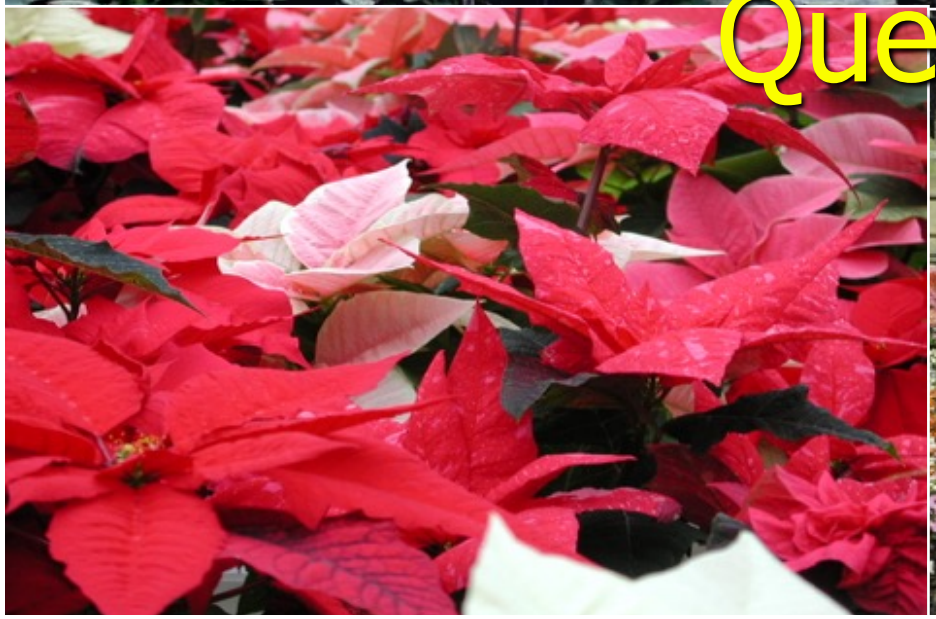
https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-technical-information-bulletin.pdf

- BASF, Biobest, Koppert guides for compatibility

https://betterplants.basf.us/content/dam/cxm/agriculture/better-plants/united-states/english/products/nemasys-beneficial-nematodes/nemasys-chemical-compatibility-guide.pdf

- Email us (jps3@cornell.edu or arg296@cornell.edu)

Thanks for Your Attention!



Questions?